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ABSTRACT

The purpose of this study was to use secondary analysis of a database known as the Third International Mathematics and Science Study (TIMSS) to examine the differences in a student's opportunity to learn mathematics and science and the differences in classroom teaching practices and delivery of the curriculum, and to investigate those variables associated with gender and socioeconomic equity in a student's mathematics and science achievement. The aim was to investigate mathematics and science achievement of 13-year-old students from four countries who participated in the TIMSS study--Australia, Canada, England and the United States--and to identify those aspects and practices of the educational systems in those countries that successfully promote student mathematics and science learning. Those factors associated with gender differences and socioeconomic differences were investigated using a multilevel model of analysis--that is, the random gender slope and the random socioeconomic status slope were both fully investigated. In order to achieve this goal, the TIMSS data were used and this study included the Australian, Canadian, English and U.S. TIMSS data. The usefulness of this research for enhancing the scientific and technological skills of a country is established both in terms of the quality and the uniqueness of the data, the untapped potential of the data bases, advanced statistical techniques, previous research experience, availability of expert advice and resources, the identification of gender and socioeconomic issues and the problem of lack of equity in mathematics and science achievement. Contains 47 references. (Author/WRM)

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Gender and Socioeconomic Equity in Mathematics and Science Education: A Comparative Study

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Gender and Socioeconomic Equity in Mathematics and Science Education

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"We believe ... that an understanding of a foreign educational system can illuminate one's own..." (Griffiths & Howson, 1974).

The purpose of this study was to use secondary analysis of a database known as the Third International Mathematics and Science Study (TIMSS) to examine the differences in a students' opportunity to learn mathematics and science and the differences in classroom teaching practices and delivery of the curriculum and to investigate those variables associated with gender and socioeconomic equity in a students' mathematics and science achievement. The aim was to investigate mathematics and science achievement of 13-year-old students from four countries who participated in the TIMSS study, Australia, Canada, England and the United States and to identify those aspects and practices of the educational systems in those countries that successfully promote student mathematics and science learning. Those factors associated with gender differences and socioeconomic differences were investigated using a multilevel model of analysis-that is, the random gender slope and the random socioeconomic status slope were both fully investigated.

In order to achieve this goal, the Third International Mathematics and Science Study data were used and this study included the Australian, Canadian, English and US TIMSS data. The usefulness of this research for enhancing the scientific and technological skills of a country is established both in terms of the quality and the uniqueness of the data, the untapped potential of the data bases, advanced statistical techniques, previous research experience, availability of expert advice and resources, the identification of gender and socioeconomic issues and the problem of lack of equity in mathematics and science achievement.

Theoretical Framework

Gender differences in science achievement has been investigated in previous large scale studies (Keeves, 1973; Comber & Keeves, 1973; Kelly, 1978), some of these studies assumed that the data had been collected as a simple random sample and therefore ignored the stratification of the sample by state/territory and school type (government, Catholic and independent) and the multilevel nature of students clustered within classes and schools. Although these studies have looked at science achievement they have not considered the mathematics achievement of the students. A distinctive methodological feature of the present research is that it employed methods of analysis which accommodated both the complex sample design and the multilevel nature of the data. Young conducted such analyses with the Second International Science Study (Young, 1991; Young & Fraser, 1993) investigating the random gender slopes and possible explanatory variables. However, this data was collected in 1984 and does not reflect the current state of affairs, nor does it consider the mathematics achievement of the students.

In most research, the areas of teacher effectiveness and school effectiveness have been investigated separately (Stringfield & Teddlie, 1991; Teddlie, 1991). Teacher effectiveness studies have been

concerned only with what goes on in classrooms and deals more productively with what teachers do than what they are like personally since the links between teacher characteristics and student achievement are apparently quiet tenuous (Organisation for Economic Co-operation and Development, 1989). Lee, Dedrick and Smith (1991) suggested that the appropriate way to conceptualise the link between schools and students, is to see it as mediated by teachers. They see teachers' perceptions and practices affecting student learning and focus on the way in which school organisation influences teachers' efficacy and satisfaction. Murphy (1989) concluded that the school environment provides the model for all learning, academic, social and emotional, though the major impact in school comes from the interactions and relations between the teacher and the learner.

Mortimore and colleagues (1988) reported that teachers in effective schools were involved in whole-school curriculum planning but developed their own curriculum guidelines. Within their own classrooms, they ensured that the school day was given structure. They provided a framework in which pupils could work and at the same time encouraged them to exercise some independence and choice of work within the framework. The classrooms have a businesslike and purposeful air. Much time is spent discussing the content of work and time for feedback is considered essential.

Results from the International Association for Educational Achievement Classroom Environment Study (Anderson, Ryan, & Shapiro, 1989) indicated that quality of instruction directly influenced academic gain. The results of this study also showed that students' 'Opportunity to Learn' (OTL) varied greatly, both between countries and classrooms within countries. Within country OTL variance of over 300% was common and that regardless of country, students who spent more time engaged in learning activities showed more academic gain. Burnstein, (1992) in a study of the Second International Mathematics Study (SIMS), found that the one variable for which the study was able to produce an unequivocal finding was Opportunity to Learn. The more exposure to mathematics and science content the students had, the higher their achievement.

> Much stronger apparently than how content is delivered is that it is delivered. While students will not learn all they have been taught, they have to be incredibly resourceful to learn mathematics to which they have not been exposed. (Kifer & Burstein, 1992, p. 339)

The conceptual framework for this study encompassed the student's home background, school characteristics and environments, and national context in relating student mathematics and science achievement with opportunity to learn and instructional practices. The Third International Mathematics and Science Study provided an opportunity to investigate gender and socioeconomic differences in mathematics and science achievement, and how they may be explained by variables at the classroom, school and home levels.

Specific Research Questions

1. How do gender and socioeconomic differences in student performance in mathematics and science differ across countries? What school, teacher and home influences tend to explain these?
2. Which educational indicators are associated with equitable student outcomes in mathematics and science education?
3. How is student achievement in mathematics and science influenced by opportunity to learn and instructional practices?

Research Plan, Methods and Techniques

Third International Mathematics and Science Study (TIMSS): Data Base and Facilities

The purpose of the proposed study was to investigate the relationship between school, teacher, student and instructional practices with respect to gender and socioeconomic differences in student outcomes in mathematics and science. For this purpose, the most up-to-date and comprehensive database collected in Australia, Canada, England and the US was used - the Third International Mathematics and Science Study (TIMSS).

The Third International Mathematics and Science Study is a comparative, international study of science and mathematics education. The goal of TIMSS was to develop a better understanding of the major attributes of science and mathematics curricula, teaching practices, and students' learning, as well as a better understanding of the linkages that exist among these components. TIMSS is designed to describe, explain, compare and contrast the current status of mathematics and science education in countries around the world. It is particularly useful to have a study incorporating mathematics and science together as this provides researchers with a unique opportunity to compare mathematics and science achievement using the same set of students. Previous studies separated mathematics and science data collections into different samples of students.

Comparative Studies

For the TIMSS, the explanation of student achievement in mathematics and science was the primary goal. Describing and explaining educational achievement is compounded when considered across international settings and information about the schools sin these two countries allows this to be accounted for. An international context is a particularly valuable one for considering the importance of variables that might account for inequities in mathematics and science achievement. Studies that cross national boundaries provide participating countries with a broader context within which to examine their own implicit theories and values and their concomitant practices. As well, comparative studies provide an opportunity to study a variety of teaching practices, curriculum goals and structures, school organisational patterns, and other different arrangements for education that might not exist in a single jurisdiction.

Sample Design

The Third International Mathematics and Science Study (TIMSS) sampled students from three population groups in 45 countries. For the purpose of this study, the second population group, thirteen-year-old students, wass used. The countries that have been selected for this study are: Australia, Canada, England and the United States. These countries were selected on the basis of their overall achievement in mathematics and science ranging from having very high mean country results to much lower results.

There are often several curricular streams within a system and these streams may occur between or within schools. It is important to be able to describe the variability of students outcomes that is a characteristic of students, of classes and of schools. To be able to do this, the sampling must permit the disentangling of the sources of variation. In this study, the classrooms are a unit of sampling and more than one classroom was sampled from each school.

The teachers who were included in this study are all high school mathematics and science teachers. Students in this study are from both private and public schools, from both single-sex and coeducational schools (See Table 1 for sample size).

Table 1. Sample of students and schools by country.

Country	Students	Schools
Australia	7253	161
Canada	8362	364
England	1776	121
United States	7087	183

Statistical Procedures Used to Investigate Hypotheses

Each of the specific research questions were investigated using statistical procedures, such as univariate analysis, multiple regression, analysis of variance and multilevel analysis procedures. Additionally, this study incorporated Rasch Analysis in order to examine individual test items for their usefulness in measuring student performance in mathematics. The aim was to establish a model linking each of the variables known to influence student achievement into a single holistic picture for all students irrespective of gender or socioeconomic status.

The experiences that children share within school settings and the effects of these experiences on their development might be seen as the basic material of educational research. Until recently, few studies have explicitly taken account of the effects of the particular classrooms and schools in which students and teachers share membership. The grouping of students, classes and schools occurs in a hierarchical order with each group influencing the members of the group in thought and behaviour (Raudenbush, 1988). The nature of these hierarchical structures produces multilevel data. The multilevel analysis used in this study addressed the problem of quantitative studies of schooling that fail to reflect the hierarchical, social organisation of schooling.

The response variables for this analysis were mathematics and science achievement. The multilevel analysis combined all of the possible explanatory variables under investigation here and revealed how they combine to influence student achievement. The explanatory variables include; socioeconomic status, gender, opportunity to learn, classroom teaching practices and other school background variables. Student and school composite scales consisted of items which were categorical, not continuous. Additionally, these items varied in their loadings which indicated that confirmatory Factor Analysis was crucial to the effective construction of the composite scale. For the purpose of this research, the Coefficient of Detrermination was used as the measure of reliability. The method used was based upon Werts, Rock, Linn and Joreskog (1978).

The amount of variation in estimates of variables affecting academic achievement across different levels of analysis cannot be ignored by serious educational researchers. Traditional linear models on which most researchers rely require the assumption that subjects respond independently, yet most subjects are 'nested' within classrooms, schools, districts, states, and countries so that responses within groups are group dependent. To ignore the nested structure of this type of data will ultimately give rise to problems of aggregation bias and imprecision (Raudenbush, 1988). The Hierarchical Linear Model provides an integrated strategy for handling problems such as

aggregation bias in standard error estimates and erroneous probability values in hypothesis testing of school effects (Bryk & Raudenbush, 1992).

Table 2. Variables in the Model

Variables	Description
Achievement	Mathematics Achievement score estimated using the Rasch Model
	Science Achievement score estimated using the Rasch Model
Gender	The sex of the student coded 1 for females and 2 for males
Socioeconomic Status	Student socioeconomic status consisted of mothers and fathers education, number of books in the home and English speaking background
Opportunity to Learn	Schools reported on the amount of time students were exposed to mathematics and science lessons each school week
Teaching Practices	
Teacher Directed	These classes are highly teacher oriented with students having minimal interaction
Practical Work	In these classes the students are engaged in a lot of practical activities and group work
Real Life	The teacher uses problems and examples that are related to everyday life

The Three-Level Multilevel Linear Model

Traditional linear models on which most researchers have relied upon, require the assumption that errors are independent, yet most subjects are 'nested' within classrooms, schools, districts, states and countries so that responses within groups are group dependent. To ignore the nested structure of this type of data ultimately will give rise to problems of aggregation bias (within-group homogeneity) and imprecision (Burstein, 1980; Raudenbush, 1988).

The Multilevel Linear Model provides an integrated strategy for handling problems such as aggregation bias in standard error estimates and erroneous probability values in hypothesis testing of school effects. For this study, MLn was chosen as the software program appropriate to study school and student effects relating to student outcomes (Woodhouse et al., 1995). Research on school effects has previously been conducted with a set of data analysed at the individual student level, with the assumption that classrooms and schools affect students equally. However, when the effects vary among individuals and their contexts, this type of statistical analysis can be misleading (Bryk & Raudenbush, 1987). Ordinary least squares analysis provides information about the total variance, but can only break this total variance into the between- and within-school effects. The between-school effect may be influenced by school level variables, such as the affluence of the school. This study endeavoured to explain variations in student outcomes by first decomposing observed relationships into between- and within-school components.

Previous studies have shown clearly that educational researchers need to account for the inherent multilevel structure of data collected from schools and this literature includes Mason et al. (1983), Bosker and Scheerens (1989), Bryk and Raudenbush (1992) and Goldstein (1984, 1987, 1995).

The Unconditional Statistical Model

In this study, the use of the multilevel linear model involved the single cross-section of data with a three-level structure consisting of students (Level 1) nested within classes (Level 2) nested within schools (Level 3). This study involved four countries, Australia, United States, England and Canada.

The simplest model was used first, that is, the fully unconditional model with no predictor variables specified. The outcome measures, science and mathematics achievement, were free to vary across three different levels of analysis: student, class and school. This model is described below in Equations 1, 2 and 3.

Student-Level Model. Science/Mathematics Achievement for each student was estimated as a function of the class average plus random error:

$$Ach_{ijk} = \pi_{0jk} + e_{ijk} \qquad \text{Equation 1}$$

where

Ach_{ijk} represents the Science/Mathematics Achievement of each student i in class j and school k.

π_{0jk} represents the class mean Science/Mathematics achievement of class j in school k.

e_{ijk} represents the random error of student i in class j and school k

$i = 1, 2, 3, \ldots, n_{jk}$ students in class j and school k.

$j = 1,2, \ldots J_k$ classes within school k,

$k = 1, \ldots, K$ schools.

Class-Level Model. Science/Mathematics achievement classroom mean varies as a function of the school mean plus random error:

$$\pi_{0jk} = \beta_{00k} + r_{0jk} \qquad \text{Equation 2}$$

where

β_{00k} represents the mean Science/Mathematics achievement in school k.

r_{0jk} represents the random error of class j within school k

School-Level Model. Science/Mathematics school mean achievement varies randomly around a grand mean for all schools.

$$\beta_{00k} = \gamma_{000} + \mu_{00k} \qquad \text{Equation 3}$$

where

γ_{000} represents the grand mean Science/Mathematics achievement for all schools.

μ_{00k} represents the random school effect, the deviation of school *k's* mean from the grand mean.

This three-level model partitions the total variability in the outcome measure, Science/Mathematics achievement, into its three components: students within classes (σ^2), classes within schools (τ_π) and between schools (τ_β).

Three Conditional Statistical Models

Upon estimation of the unconditional model, three further conditional models were estimated in order to investigate the effects of the student sex, student socioeconomic status, oportunity to learn and different teaching practices (Teacher Directed, Practical Work and Real Life). Additionally, these models were estimated separately for science and mathematics achievement. The three generic statistical equations are presented below (Equations 4 to 7).

$$\begin{aligned} Ach_{ijk} = \quad & \pi_{0jk} + \pi_{1jk}(Gender_{ijk}) + \pi_{2jk}(SES)_{ijk} \\ \pi_{0jk} = \quad & \beta_{00k} + r_{0jk} \\ \pi_{1jk} = \quad & \beta_{100} \\ \pi_{2jk} = \quad & \beta_{200} \\ \beta_{00k} = \gamma_{000}, + \quad & \mu_{00k} \end{aligned}$$

Equation 4

$$\begin{aligned} Ach_{ijk} = \quad & \pi_{0jk} + \pi_{1jk}(Gender_{ijk}) + \pi_{2jk}(SES_{ijk}) + \pi_{3jk}(OppLearn_{ijk}) \\ \pi_{0jk} = \quad & \beta_{00k} + r_{0jk} \\ \pi_{1jk} = \quad & \beta_{100} \\ \pi_{2jk} = \quad & \beta_{200} \\ \pi_{3jk} = \quad & \beta_{300} \\ \beta_{00k} = \gamma_{000}, + \quad & \mu_{00k} \end{aligned}$$

Equation 5

$$\begin{aligned} Ach_{ijk} = \quad & \pi_{0jk} + \pi_{1jk}(Gender_{ijk}) + \pi_{2jk}(SES_{ijk}) + \pi_{3jk}(OppLearn_{ijk}) + \pi_{4jk}(TeachDir_{ijk}) \\ & +\pi_{5jk}(Practical_{ijk}) +\pi_{6jk}(RealLife_{ijk}) + e_{ijk} \\ \pi_{0jk} = \quad & \beta_{00k} + r_{0jk} \\ \pi_{1jk} = \quad & \beta_{100} \\ \pi_{2jk} = \quad & \beta_{200} \\ \pi_{3jk} = \quad & \beta_{300} \\ \pi_{4jk} = \quad & \beta_{400} \\ \pi_{5jk} = \quad & \beta_{500} \\ \pi_{6jk} = \quad & \beta_{600} \\ \beta_{00k} = \gamma_{000}, + \quad & \mu_{00k} \end{aligned}$$

Equation 6

Table 3: Three level unconditional variance components model

		Science Achievement Estimate (s.e)				Mathematics Achievement Estimate (s.e)			
Level of Analysis	Parameter	Australia	United States	England	Canada	Australia	United States	England	Canada
Fixed Model	Constant	1.095(.082)	1.132(.701)	.968(.030)	1.401(.030)	.988(.095)	1.001(.100)	1.030(.411)	.976(.081)
Random Model									
School	Constant	.035(.067)	.148(.093)	.101(.089)	.298(.002)	.142(.082)	.203(.080)	.191(.077)	.048(.015)
Class	Constant	.645(.085)	.701(.086)	.443(.099)	.309(.081)	.633(.081)	.813(.090)	.463(.087)	.202(.100)
Student	Constant	.792(.033)	.813(.045)	.700(.101)	.543(.097)	1.091(.074)	.998(.094)	.589(.111)	.363(.037)
Total		1.472	1.662	1.244	1.15	1.866	2.014	1.243	0.613

Table 4: Percentage Variance Unexplained at each level

		Science Achievement Percentage Variance Unexplained				Mathematics Achievement Percentage Variance Unexplained			
Level of Analysis	Parameter	Australia	United States	England	Canada	Australia	United States	England	Canada
Random Model									
School	Constant	2.4%	12.7%	8.1%	25.9%	7.6%	10.1%	15.4%	7.8%
Class	Constant	43.8%	42.2%	35.6%	26.8%	33.9%	40.4%	37.2%	32.9%
Student	Constant	53.8%	48.9%	56.3%	47.2%	58.5%	49.6%	47.4%	59.2%

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Table 5: Student Background Variables

		Science Achievement Estimate (s.e)				Mathematics Achievement Estimate (s.e)			
Level of Analysis	Parameter	Australia	United States	England	Canada	Australia	United States	England	Canada
Fixed Model	Constant	1.987(.164)	2.083(.098)	1.989(.056)	2.231(.566)	1.086(.165)	2.199(.101)	.978(.056)	1.236(.111)
	SES	.199(.076)	.401(.005)	.361(.009)	.222(.008)	.206(.003)	.998(.090)	.587(.006)	.468(.036)
	Gender	.369(.099)	.268(.010)	.211(.053)	.343(.073)	.500(.081)	.501(.121)	.698(.041)	.661(.023)
Random Model									
School	Constant	.001(.000)	.020(.001)	.011(.003)	.201(.020)	.004(.001)	.098(.008)	.102(.006)	.011(.006)
Class	Constant	.590(.059)	.588(.098)	.361(.021)	.281(.008)	.501(.089)	.703(.009)	.398(.034)	.168(.063)
Student	Constant	.762(.014)	.761(.020)	.493(.102)	.298(.010)	.806(.010)	.865(.019)	.356(.113)	.212(.009)

Table 6: Percentage variance explained by Student Background Variables

		Science Achievement Percentage Variance Explained				Mathematics Achievement Percentage Variance Explained			
Level of Analysis	Parameter	Australia	United States	England	Canada	Australia	United States	England	Canada
Random Model									
School	Constant	97.1%	86.5%	89.1%	32.6%	97.2%	51.7%	46.6%	77.0%
Class	Constant	8.5%	16.1%	18.5%	9.15	20.8%	13.5%	14.0%	16.8%
Student	Constant	3.8%	6.4%	20.75	45.15	26.1%	13.3%	39.6%	41.6%

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Results

Firstly, the variation in student science and mathematics achievement was decomposed at the three levels; school, classroom and student. Secondly, two student level variables, sex and socioeconomic status were included in this three level model. Two further models were analysed, one adding students opportunity to learn to the previous model and one adding the three teaching practices, Teacher Directed, Practical Work and Real Life. The variance estimates and standard errors for all countries and for both science achievement and mathematics achievement in these four models are shown in Tables 3, 5, 7 and 9.

The percentage of variation explained by these models is reported in Tables 4, 6, 8 and 10. For all four countries, most of the variation in science and mathematics achievement in the unconditional model is explained at the student level. These results indicate that little of the variation in achievement is explained at the school level with the exception of science achievement in Canada where 25.9% of science achievement is explained at the school level. In England, 15.4% of the variation in mathematics achievement is explained at the school level, which is also considered high.

Effect of Student Background Variables on Student Achievement

For Australia, most of the school level variance in achievement is explained by the inclusion of student background variables in the model, 97.1 % for science and 97.2 % for mathematics. In the United States (86.5%) and England (89.1%), this is true for science achievement but the percentages are lower for mathematics achievement, United States (51.76%) and England (46.6%). The results for Canada are the reverse, only 32.6% of the variation in science achievement at the school level are further explained by student background variables, and 77.0% of the variation in mathematics achievement. The results in Table 4 show that the effects of gender and SES are all strong and significant (significant being greater than two standard errors).

In Australia and the United States, very little of the student level variance in science achievement is further explained by gender and SES. In Canada, 45.15% of the student level variance in science achievement is further explained by gender and SES, and 41.6% of the student level variance in mathematics achievement. In England, 20.75%. For science achievement, and 39.6% for mathematics achievement. These percentages are high when compared to those for Australia (26.1%) and the United States (13.3%).

Effect of Student Opportunity to Learn on Student Achievement

The effect of Opportunity to Learn on student achievement was analysed by adding this variable to the model (Table 7). These analyses showed that opportunity to learn had a strong and positive effect on student achievement in both science and mathematics. Opportunity to learn was a measure of the number of hour's exposure that students had to science and mathematics in a week.

The amount of unexplained variance further explained by adding opportunity to learn to the model differs across countries. At the school level for each country there is very little or no further variance explained. At the class level for Australia, the United States and England a large amount of unexplained variance in science achievement is further explained by adding opportunity to learn to the model. In Canada only 8.1% of the variance in science achievement is further explained at the class level. All four countries are similar in the amount of variance further explained in mathematics

		Science Achievement Percentage Variance Explained				Mathematics Achievement Percentage Variance Explained			
Level of Analysis	Parameter	Australia	United States	England	Canada	Australia	United States	England	Canada
Random Model									
Fixed Model	Constant	-3.011(.057)	-2.988(.101)	-2.064(.203)	-1.369(.106)	-3.088(.066)	-3.003(.087)	-.132(.055)	-1.598(.128)
	SES	.109(.056)	.289(.060)	.396(.053)	.521(.065)	.299(.070)	.376(.088)	.531(.063)	.307(.007)
	Gender	.581(.056)	.778(.040)	.566(.089)	.168(.009)	.301(.101)	.494(.005)	.249(.201)	.379(.181)
	Opportunity to Learn	.380(.023)	.401(.032)	.365(.187)	.254(.101)	.388(.049)	.321(.101)	.137(.073)	.214(.108)
Random Model									
School	Constant	.001(.000)	.000(.000)	.011(.003)	.199(.055)	.000(.000)	.080(.001)	.098(.002)	.006(.000)
Class	Constant	.364(.019)	.310(.010)	.215(.101)	.256(.005)	.401(.098)	.632(.081)	.311(.036)	.150(.100)
Student	Constant	.401(.002)	.497(.200)	.301(.006)	.165(.036)	.698(.101)	.776(.090)	.213(.036)	.156(.004)

Table 8: Percentage variance explained by Students Opportunity to Learn

		Science Achievement Percentage Variance Explained				Mathematics Achievement Percentage Variance Explained			
Level of Analysis	Parameter	Australia	United States	England	Canada	Australia	United States	England	Canada
Random Model									
School	Constant	0%	13.5%	0%	6.7%	2.8%	8.9%	6.8%	10.4%
Class	Constant	35.0%	39.7%	32.9%	8.1%	15.7%	8.7%	18.8%	8.9%
Student	Constant	45.6%	32.5%	27.4%	19.05	9.9%	8.9%	24.2%	15.4%

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Table 9: Teaching Practices

		Science Achievement Estimate (s.e)				Mathematics Achievement Estimate (s.e)			
Level of Analysis	Parameter	Australia	United States	England	Canada	Australia	United States	England	Canada
Fixed Model	Constant	-2.363(.398)	-1.890(.401)	-2.001(.654)	-1.987(.089)	-3.010(.494)	-2.890(.986)	-3.440(.589)	-.258(.136)
	SES	.081(.056)	.306(.078)	.400(.051)	.699(.258)	.199(.079)	.297(.081)	.397(.089)	.569(.301)
	Gender	.631(.040)	.411(.101)	.098(.003)	.369(.236)	.501(1.77)	.309(.108)	.449(.287)	.237(.098)
	Opportunity to Learn	.491(.056)	.206(.098)	.158(.021)	.288(.030)	.201(.091)	.089(.002)	.164(.078)	.365(.078)
	Teacher Directed	-.165(.031)	-.281(.088)	-.302(.136)	-.599(.039)	-.120(.020)	-.251(.100)	-.632(.201)	-.525(.203)
	Practical Work	.037(.021)	.142(.060)	.089(.004)	.403(.099)	.170(.062)	.200(.111)	.436(.273)	.361(.167)
	Real Life	.041(.021)	.143(.009)	.233(.058)	.301(.113)	.108(.008)	.098(.005)	.188(.009)	.279(.096)
Random Model									
School	Constant	.001(.000)	.000(.000)	.011(.003)	.165(.008)	.000(.000)	.078(.005)	.098(.002)	.006(.000)
Class	Constant	.121(.025)	.106(.030)	.199(.052)	.210(.001)	.320(.002)	.404(.098)	.258(.004)	.139(.101)
Student	Constant	.324(.015)	.398(.042)	.256(.021)	.121(.010)	.598(.010)	.577(.065)	.156(.004)	.109(.007)

Table 10: Percentage variance explained by Teaching Practices

		Science Achievement Percentage Variance Explained				Mathematics Achievement Percentage Variance Explained			
Level of Analysis	Parameter	Australia	United States	England	Canada	Australia	United States	England	Canada
Random Model									
School	Constant	0%	0%	0%	11.4%	0%	1.0%	0%	0%
Class	Constant	37.6%	27.8%	15.8%	14.9%	12.8%	28.0%	11.4%	5.4%
Student	Constant	9.7%	13.3%	6.4%	8.2%	9.2%	22.8%	9.7%	12.9%

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achievement (Table 8). There is a lot of further variance explained at the student level for all countries for science achievement and in England for mathematics achievement. These results are all reported in table 8.

Effect of Teaching Practices on Student Achievement

The teaching practices for each of the four countries were categorised into three variables. Those teachers who were very dictorial and used the more traditional teacher centred approach in their classes were categorised 'Teacher Directed'. Those teachers who employed a lot of practical work and investigation and group work in their classes were categorised 'Practical Work'. The teachers who made every effort to include in their lessons situations that related to real life and to relate the learning to every day were categorised 'Real Life'.

The effects of the different types of teaching practices were analysed by including the three categories to the model. Teacher Directed practices had a negative effect on both science and mathematics achievement and this was strong and significant. For all countries in this study the data show that teachers who employ these methods have students who are not achieving as well as others. The effect of Practical Work and Real Life both had strong, positive and significant effects on student achievement. The two exceptions, the United States and England, did not have a significant effect for Practical Work although this effect remains positive (Table 9).

The percentage of variance further explained at the school level is only evident in Canada for mathematics achievement (11.4%). For all other countries there is no further variance explained at the school level. At the class level, the amount of unexplained variance was reduced by considerable amounts for both science and mathematics achievement (See Table 10). Canada had the lowest percentage reduction for mathematics achievement (5.4%). The unexplained variance at the student level is further reduced for all of the countries in the study. Of particular interest is the United States with 22.8% of the variance further explained for mathematics achievement.

Discussion

This study involved a comparison of four countries, Australia, England, the United States and Canada. The outcome measures investigate were student science and mathematics achievement. The multilevel linear model was used to combine the variables under investigation and to proportion variance in student achievement at the three levels; school, class and student. The unconditional three level model showed that most of the variance in student achievement was accounted for at the student level but significant percentages were also explained at the class level. Canada was one exception with 25.9% of the total variance in science achievement being explained at the school level and England another with 15.4% of the total variance in mathematics achievement being explained at the school level. These results demonstrate the need to use a multilevel approach to explaining variance in student achievement and that generalisations cannot be made across countries.

The literature indicates that student gender and socioeconomic status account for a degree of variance in student achievement and this study has shown that most of that variance is explained at the student level. Of the school level differences, most of these were explained by the inclusion of gender and socioeconomic status in the model but overall these were small in explaining differences in student achievement. Canada and England stand out as being different from Australia and the United States as they much have higher percentages of variance further explained by gender and SES at the student level.

Kifer and Burstein (1992) believed that the more exposure students had to learn the more sucessful they are likely to be. To this end the next model of analysis included the variable Opportunity to Learn. These data support this belief. All the results for all countries were positive and significant, the more exposure to science and mathematics the better the achievement levels. The variance further explained at the three levels showed differences between the countries. Australia, the United States and England showed more variance further explained at the class level than Canada (See Table 8). There was no unexplained variance at the school level in science achievement for both Australia and England where other countries had some unexplained variance at this level for both science and mathematics achievement. These differences show the need for further studies to understand what is happening in schools in other countries and to investigate further the reasons for some countries to have more unexplained variance at different levels.

As students are clustered in classes, it is necessary to consider the class as a unit of analysis and also to investigate the effect of the teachers beliefs and practices in teaching in the class. These data showed three teaching practices that were evident by the results of the univariate analysis. The analysis that included these variables in the model revealed that the teaching practices in these four countries had similar effects on student achievement. All were strong and significant effects with Teacher Directed being negative. Students from all four countries performed better in classes where the teacher was more student centred and relevant. The results do indicate that teaching practices are influential on student achievement.

These independent variables included in this analysis do not explain all of the variance in student achievement. Further study into the teaching pedagogy is required to further explain what is happening in these classrooms and how this is impacting on student achievement. This study is limited in that the teaching practices have been categorised into three variables on the basis of student responses. A study of this nature can be enhanced by qualitative investigation into selected classrooms to see a picture of what is happening.

A study such as TIMSS provides an unparalleled opportunity to compare and contrast the common and unique features of education systems. Although a survey such as TIMSS can never definitively explain student achievement, it can explore the plausibility of many hypothetical reasons for it; perhaps eliminating some and lending support to others. Insights into the possibilities of educational practice should lead to the improvement of education.

References

Anderson, L.D., Ryan, W., & Shapiro, B. (1989). *The IEA Classroom Environment Study*. Oxford, Pergamon Press.

Australian Education Council (1991). *Young people's participation in post-compulsory education and training: Report of the Australian Education Council Review Committee*. Canberra: Australian Government Publishing Service. (Finn Report).

Australian Education Council (1992). *Putting general education to work: The key competencies report*. Canberra: Australian Government Publishing Service. (Mayer Report).

Bryk, A.S., & Raudenbush, S.W. (1987). Application of hierarchical linear models to assessing change. *Psychological Bulletin*, 101, 147-158.

Bryk, A.S., & Raudenbush, S.W. (1992). *Hierarchical linear models: Applications and data analysis methods* (Advanced Quantitative Techniques in the Social Sciences 1). Newbury Park, California: Sage Publications, Inc.

Burstein, L. (ed.). (1992). *The IEA study of mathematics 111: Student growth and classroom processes*.. Oxford, Pergamon Press.

Commonwealth Schools Commission (1987). *The National Policy for the Education of Girls in Australian Schools.* Canberra: Commonwealth Schools Commission.

Connell, R.W., Ashden, D.J., Kessler, S., & Dowsett, G.W. (1982). *Making the difference - school, families and social division.* Sydney: Allen & Unwin.

Comber, L.C., & Keeves, J.P. (1973). *Science education in nineteen countries*: An empirical study. International Studies in Evaluation 1 Stockholm: Almqvist and Wiksell.

Fraser, B. J., Walberg, H. J., Welch, W.W. & Hattie, J.A. (1987). Syntheses of educational productivity research. *International Journal of Educational Research, 11*, 145-252.

Goldstein, H. (1984). The methodology of school comparisons. *Oxford Review of Education, 10*, 69-74.

Goldstein, H. (1987). *Multilevel models in educational and social research.* London: Charles Griffin & Co.

Goldstein, H. (1995*). Multilevel statistical models.* London: Arnold, Hodder Headline Group.

Griffiths, H.B., & Howson, A.G. (1974*). Mathematics, society and curricula.* Cambridge: Cambridge University Press.

Kahle, J. B. (1985). *Women in science: A report from the field.* Philadelphia: Falmer Press.

Keeves, J P. (1973). Differences between the sexes in mathematics and science courses. *International Review of Education, 19*(1), 47-63

Keeves, J. P. (1992). *The IEA study of science III: Changes in science education and achievement: 1970 to 1984.* Oxford: Pergamon Press.

Kelly, A. (1978). *Girls and science: an international study of sex differences in school science achievement.* (International Association for the Evaluation of Educational Achievement IEA Monograph Studies No. 9). Stockholm, Sweden; Almqvist and Wicksell International.

Kifer, & Burstein, L. (1992). Concluding thoughts: What we know, what it means. In L. Burnstein (eds.*) The IEA study of mathematics 111: Student growth and classroom processes.* Oxford, Pergamon.

King, R. (1971). Unequal access in education - sex and social class. *Social and Economic Administration, 5*, 3.

King, R. (1987). Sex and social class inequalities in education: A re-examination. *British Journal of Sociology of Education, 8*(3), 287-303.

Lee, V., Dedrick, R. & Smith, J. (1991). The effect of the social organisation of schools on teachers' efficacy and satisfaction. *Sociology of Education, 64*(13), 190-208.

Mortimore, P., Sammons, P., Stopll, L., Lewis, D., & Ecob, R. (1988). *School matters: The union years.* Somerset, UK: Open Books.

Organisation for Economic Co-operation and Development (OECD) (1989). *Schools and quality.* Paris: OECD.

Plomp, T. (1992). Conceptualising a comparative educational research framework. In W. Loxley (Ed). *Monitoring the quality of education world-wide.* The Hague. Netherlands.

Postlethwaite, T.N., & Wiley, D.E. (1992). *The IEA study of science II: Science achievement in twenty-three countries.* Oxford: Pergamon Press.

Powles, M. (1987). *Women's participation in tertiary education: A review of recent Australian research.* Second Edition. Melbourne: The University of Melbourne.

Raudenbush, S.W. (1988). *Educational applications of hierarchical linear models: A review. Journal of Educational Statistics, 13*(20), 85-116.

Rosier, M. J., & Keeves, J.P. (1991). *The IEA study of science I: Science education and curricula in twenty-three countries.* Oxford: Pergamon Press.

Shavelson, R. J. (1990). Application of indicator models to IEA studies. In J. Ammerlaan & W. Loxley (Eds), *Proceedings of the IEA invitational workshop on the Third International*

Mathematics and Science Study (TIMSS). The Hague, The Netherlands: IEA-Headquarters, International Association for the Evaluation of Educational Achievement.

Shavelson, R. J., MacDonnell, L.M., & Oakes, J. (1989). *Indicators for monitoring mathematics and science education: A sourcebook* (R-3742-NSF/RC). Santa Monica, California: The RAND Corporation.

Stigler, J.W., & Perry, M. (1988). Cross-cultural studies of mathematics teaching and learning recent findings and new directions. In D. A. Grouws, T. J. Cooney, & D. Jones (Eds). *Effective Mathematics Teaching* (pp. 194-223). Virginia: National Council of Teachers of Mathematics.

Weber, M. (1948). *From Max Weber: Essays in sociology.* London: Routledge & Kegan Paul.

Weber, M. (1968). *Economy and society: An outline of interpretative sociology.* New York: Bedminster.

Young, D. J. (1990). The investigation of school effects on student achievement in science: A multilevel analysis of educational data. *Research in Science Education, 20,* 306-315.

Young, D.J. (1991a). Gender differences in science achievement: Secondary analysis of data from the Second International Science Study. Doctoral thesis, Science and Mathematics Education Centre, Curtin University of Technology, Perth.

Young, D. J. (1991b, July). Multilevel analysis of sex and other factors influencing science achievement. In L. J. Rennie, L. H. Parker & G. M. Hildebrand (Eds.), *Action for Equity: The Second Decade. Contributions to the sixth international GASAT conference. Volume one: Schooling* (p. 383-391). Perth: National Key Centre for School Science and Mathematics, Curtin University of Technology.

Young, D.J. (1993a, April). Sex bias in science achievement and the Hierarchical Linear Model: An analysis of the Australian Second International Science Study. Paper presented at the Seventh annual International Objective Measurement Workshop, Emory University, Atlanta, Georgia, 10-11 April 1993.

Young, D.J. (1993b, April). Socioeconomic effects on science achievement. Paper presented at the annual meeting of the American Educational Research Association, Atlanta, Georgia, 15-18 April 1993.

Young, D.J. (1994a). Single-Sex schools and physics achievement: Are girls really advantaged? *International Journal of Science Education, 16*(3), 315-325.

Young, D.J. (1994b). A comparison of student performance in Western Australian schools: Rural and urban differences. *The Australian Educational Researcher, 21*(2), 87-105.

Young, D.J. (1995). The effect of the science learning environment on science achievement: A comparison of 12 countries from the IEA Second International Science Study. *Educational Research and Evaluation, 1*(2), 129-158.

Young, D.J., & Fraser, B.J. (1992, April). *Sex differences in science achievement: A multilevel analysis.* Paper presented at the Annual Meeting of the American Educational Research Association. San Francisco.

Young, D.J., & Fraser, B.J. (1993). Socioeconomic and gender effects on science achievement: An Australian perspective. *School Effectiveness and School Improvement, 4*(4), 265-289.

Young, D.J., & Fraser, B.J. (1994). Gender differences in science achievement: Do school effects make a difference. *Journal of Research in Science Teaching, 31*(8), 857-871.

Young, D.J., Reynolds, A., & Walberg, H.J. (1996). Science achievement and the educational productivity model: A hierarchical linear model. *The Journal of Educational Research, 89*(5), 272-278.

Werts, C.,E., Rock, D.R., Linn, R.L., & Joreskog, K.G. (1978). A general method of estimating reliability of a composite. *Educational and Psychological Measurement, 38,* 933-938.

Woodhouse, G., Rasbash, J., Goldstein, H., Yang, M., Howarth, J., & Plewis, I. (1995). *A guide to Mln for new users.* London: Institute of Education, University of London.